On the Definition of El Niño and El Niño-Season Average U.S. Weather Anomalies

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Abstract.

Examination of seasonal U.S. weather anomalies associated with the new NOAA definition of El Niño shows marked differences with associations found using conventional El Niño years. The new NOAA definition adds 8 years to the 12 conventional years in the period 1950–2004. Compositing these additional years generally shows a pattern mismatch with the conventional years. Using the combined years mixes the patterns of both, but with reduced amplitude and spatial extent. Thus the new El Niño definition provides a weaker basis for U.S. seasonal prediction, and may also for global weather.

1. Introduction

The El Niño–Southern Oscillation is a coupled ocean-atmosphere tropical Pacific phenomenon with global reach. Associated regional weather anomalies during the boreal fall, winter, and spring of an El Niño event have been documented around the globe (Ropelewski and Halpert 1987; 1996). There are substantial anomalies in U.S. seasonal temperature and precipitation (e.g., Harrison and Larkin 1998b, hereafter HL98b; Smith et al. 1999). When the anomalies are statistically significant and robustly associated with El Niño years they can contribute seasonal temperature and precipitation forecast skill during an El Niño year. In contemporary practice these associations provide a foundation for U.S. Seasonal forecasts.

Studies of El Niño have differed to some extent in the years selected as Year(0) of the events (the year of onset of equatorial Pacific SST warming as defined by Rasmusson and Carpenter (1982) due to differences in the "El Niño Index" used (e.g., SST anomaly over different regions of the tropical Pacific, Darwin SLP anomaly, Southern Oscillation Index, etc.) and in the index threshold chosen. Despite these differences, the Yr(0)s identified vary only marginally. However, differences of opinion have prevented agreement of a formal internationally accepted definition of El Niño years. The U.S. National Oceanic and Atmospheric Administration has recently issued an official definition of El Niño and La Niña (NOAA 2003). The existence of this definition requires re-examination of U.S. seasonal temperature and precipitation anomalies to determine what, if any, differences exist between the anomalies associated with the new definition and those associated with the conventional years.

Using seasonal temperature and precipitation anomalies from the U.S. Climate Division data set (NCDC 1994), we compare anomalies associated with the conventional years, the additional years identified by the new definition, and the combined total years. We first examine the average seasonal anomalies for boreal fall (S-O-N), winter (D-J-F) at the maximum of the events and for the subsequent spring (M-A-M), and summer (J-J-A). We also examine the significance of the likelihood that an extreme seasonal anomaly (top 20%) will be associated with an El Niño. Using these results we evaluate the benefit of the new El Niño definition of El Niño events for U.S. seasonal weather forecasting.

2. Data and Methods

Rasmusson and Carpenter (1982) first identified the El Niño–Southern Oscillation phenomenon by compositing tropical Pacific SST, wind, and SLP anomalies for a set of six El Niño events identified with anomalous Christmas-time warming off the coast of Peru. Since this seminal work, many additional studies have used a variety of indices including eastern equatorial SST (NINO 3, 4, 3.4), SLP, and others to identify the starting years (Year(0)s) of El Niño events. Most studies, such as HL98b, who used a multivariate eastern equatorial Pacific index of the robust El Niño features (Bjerknes ENSO Index, *Harrison and Larkin,* 1998a), have identified 1951, 1953, 1957, 1965, 1969, 1972, 1976, 1982, 1987, 1991 as El Niño Yr(0)s. 1953 is sometimes omitted; 1963 and 1986 are sometimes added along with a handful of less-used years, but the above list substantially holds for the period 1950–1995 (e.g., Rasmusson and Carpenter 1982; Kiladis and Diaz 1989; Deser and Wallace 1990, note warm Pt. Chicama, Peru SST for 1958, and equatorial Pacific SST for 1979; Trenberth 1996, adds 1968; Hoerling et al. 1997, add 1994). Because these years have been standardly used, we identify these years as the conventional El Niño years here.

The National Oceanic and Atmospheric Administration has recently defined El Niño as:

> A phenomenon in the equatorial Pacific Ocean characterized by a positive sea surface temperature departure from normal (for the 1971–2000 base period) in the Niño 3.4 region greater than or equal in magnitude to 0.5°C, averaged over three consecutive months. (NOAA 2003)

El Niño events are understood to have a life cycle (e.g., Rasmusson and Carpenter, 1982; Harrison and Larkin, 1998) in which the first year of equatorial Pacific SST warming is designated as Yr(0). We identify Yr(0)s of El Niño events as the first year in which the 3-month running mean of the NINO3.4 index is continuously greater than 0.5°C, as computed by NOAA CPC (⟨`http://www.cpc.noaa.gov`⟩). The period 1986–1988 is the longest run of NINO3.4 > 0.5°C; we identify both 1986 and 1987 as Yr(0)s. Eight additional El Niño Yr(0)s result during the period 1950–2004 (Table 1).

To compute the U.S. seasonal anomaly associations, we use the NCDC climate division data set (NCDC 1994) and follow the methodology of HL98b. U.S. temperature and precipitation anomalies are computed as deviations from the 1950–1995 average value. Seasonal average composites are done by calendar month over a 3-month period using data from S-O-N of Yr(0) for the Autumn season, D-J-F of Yr(0)-Yr(1) for Winter, M-A-M of Yr(1) for Spring, and J-J-A of Yr(1) for Summer. Statistical significance of the average anomalies is done using a Bootstrap technique. Extreme seasonal anomalies are defined as those in the upper quintile. Probabilities of extreme seasonal anomalies are computed by counting the number of extreme seasonal anomalies found during the set of El Niño years (conventional or additional). Statistical significance of the probability of extreme seasonal anomalies is computed explicitly from the random probability of each year being an extreme season.

3. Results

Figure 1 shows the Autumn(0), Winter(0), Spring(1), and Summer(1) U.S. temperature anomalies computed for the updated conventional (CONV, left two columns), additional (ADD, 3rd column), and total (TOTAL, right column) sets of El Niño years. For the CONV set, the unmasked average anomalies are presented along with the same anomalies masked for 80% ($p = 0.2$) statistical significance using a Bootstrap technique. Only the ADD and TOTAL masked anomalies are presented.

The CONV list used here is the same as in HL98b with the addition of 1997 and 2002. Adding these two events to the ten 1951–1991 events used in HL98b does not significantly alter the U.S. seasonal impacts. Inclusion of the strong 1997 El Niño event here introduces some broadening and increase in amplitude of the Winter north central U.S. warm anomaly. Detail changes are introduced in the results for other anomalies, but no wide-spread differences appear.

The masked-average seasonal temperature anomalies associated with the additional El Niño years are shown in the third column of Figure 1, masked for statistical significance. In general the statistically significant ADD temperature anomalies do not overlap the CONV anomalies spatially; Table 2 presents the spatial correlation statistics between ADD and CONV statistically significant anomalies. Spring and summer anomalies have the highest correlation at only $\sim$0.3; autumn and winter are $\pm$0.1.

The rightmost column of Figure 1 shows the statistically significant anomalies when all 20 El Niño events are used (TOTAL). The net effect is generally to weaken the amplitude and extent of the statistically significant seasonal anomalies. In winter and spring the TOTAL anomalies are the weakened sum of the CONV and ADD anomalies. In autumn TOTAL shows almost no statistically significant anomalies; in summer TOTAL shows only very weak warm anomalies.

Figure 2 presents the seasonal average precipitation anomalies in the same format. While more spatially complex than the temperature anomalies, a basic mismatch of patterns is again seen between the conventional and additional years. Only the winter spatial correlation is positive (0.25, Table 2), resulting from four small areas of U.S. The TOTAL anomalies are reduced due to this mismatch.

Figure 3 details where the likelihood of extreme seasonal winter anomalies is statistically significantly increased at the 80, 90, 95, and 99% levels. The CONV events show enhanced occurrence of seasonal temperature extremes throughout much of the country. Using the combined TOTAL events less of the country is covered, the pattern is more broken up, and the significance of the enhancement is reduced almost everywhere. The scattered nature of the precipitation results makes it harder to compare patterns, and while some overlap exists, fewer regions of the country have significant enhancement, and the significance level is generally reduced using the TOTAL list. While we show only wintertime seasonal extremes here, this basic comparison also holds true for Autumn(0), Spring(1), and Summer(1) anomalies.

4. Discussion

El Niño can be defined in a number of different ways. The conventionally defined El Niño years have statistically useful seasonal temperature and precipitation anomalies over much of the U.S. during the Autumn(0), Winter(0), Spring(1), and Summer(1) of the event. These relationships are an important basis for present U.S. seasonal weather forecasting. The U.S. NOAA has recently adopted a definition that leads to roughly twice as many years being classified as El Niño years as are classified under more conventional definitions. We have here examined some effects of adopting the NOAA definition of El Niño years on El Niño-average U.S. seasonal temperature and precipitation anomalies, compared with the conventional average anomalies by comparing composites for the conventional, additional, and total event lists. The addition of two El Niños, 1997 and 2002, does not significantly alter the results of HL98, indicating that these El Niños substantially followed the patterns of the conventional post-1950 events.

We find that the additional years added by the NOAA definition, however, generally show a pattern mismatch with the conventional years. The statistically significant temperature and precipitation anomalies averaged over the additional years tend to be either few in number, amplitude, and spatial extent or are different in sign and location from those averaged over the conventional El Niño years. The upper quintile extreme anomaly statistics also tend to exhibit fewer useful relationships with the additional list than are found with the conventional list. These results are not significantly altered by trend or by small changes to the specific years classified as "additional."

The effect of combining the conventional and additional years is to mix the patterns of both. The total associations show signals from both the conventional and additional composites, but with reduced amplitude and spatial extent; some of the major differences follow. Nearly all associations outside of the Pacific Northwest are eliminated in autumn. In winter, the prominent conventional northern U.S. warm anomaly is significantly reduced in both amplitude and extent, and a new region of cool anomaly appears across the southeast. In spring, the conventional wet central Atlantic anomaly is no longer present; in summer the Pacific Northwest warm anomaly disappears. We note that the total wintertime associations strongly resemble the DJF 2004-5 outlook recently issued by NOAA.

Including the additional years dilutes the statistical power and can also alter the patterns of the U.S. seasonal anomalies. Thus the NOAA definition of El Niño generally provides a weaker basis for U.S. seasonal prediction. Until it is known whether similar results apply to other El Niño associations, caution should be exercised in applying the NOAA El Niño definition.

5. References

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Table 1: Conventional and additional El Niño yr(0)s. The conventional yr(0)s are taken from Harrison and Larkin (1998). The additional years are those added by using the NOAA El Niño definition. See section 2 for details.

Conventional El Niño Yr(0)s	Additional El Niño Yr(0)s
1951	
1953	
1957	
	1963
1965	
	1968
1969	
1972	
1976	
	1977/1979
1982	
	1986
1987	
1991	
	1993
	1994
1997	
2002	
	2003

Table 2: Net correlation between statistically significant anomalies associated with conventional El Niño years and with additional El Niño years. Correlations are computed across climate divisions with no area weighting.

	Temp	Precip
Autumn	−0.13	−0.01
Winter	0.11	0.25
Spring	0.33	−0.02
Summer	0.29	−0.20

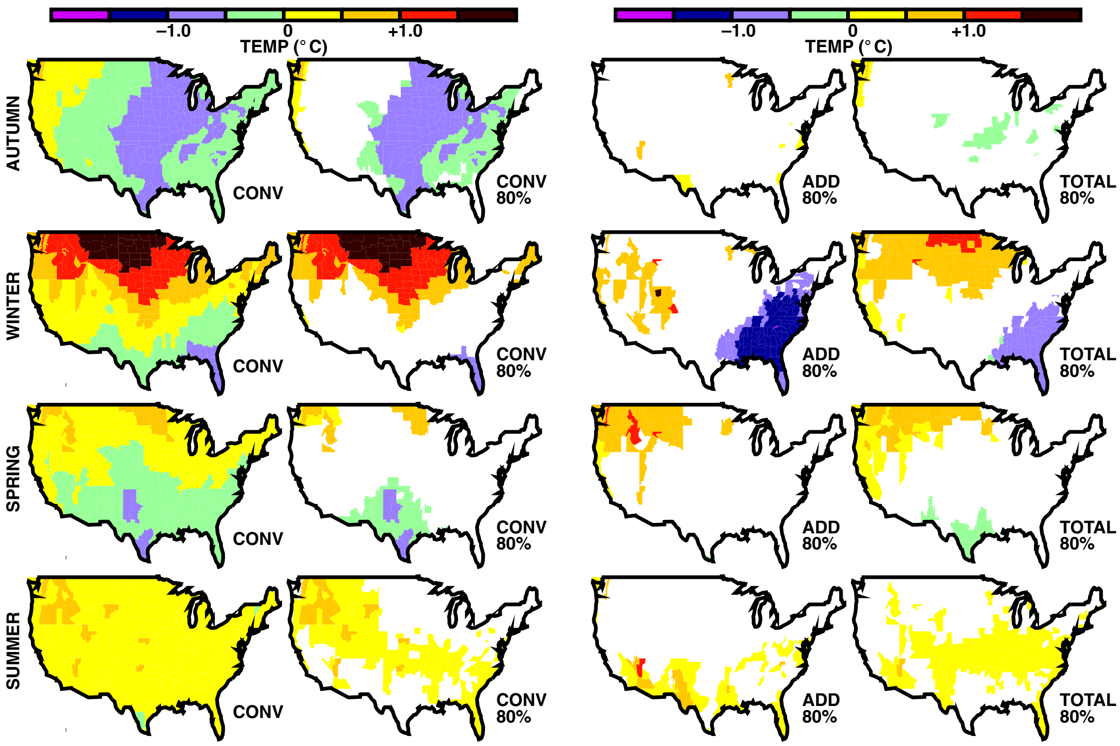

Figure 1: El Niño-Seasonal Average U.S. Temperature Anomaly Associations for Autumn(SON), Winter(DJF), Spring(MAM), and Summer(JJA). The left columns are based on the conventional 1950–2003 El Niño years (CONV); the right columns are based on the additional years included by the NWS definition (ADD). Columns 1 and 3 show all anomalies, while columns 2 and 4 mask these for 80% statistical significance (Bootstrap). See text for details.

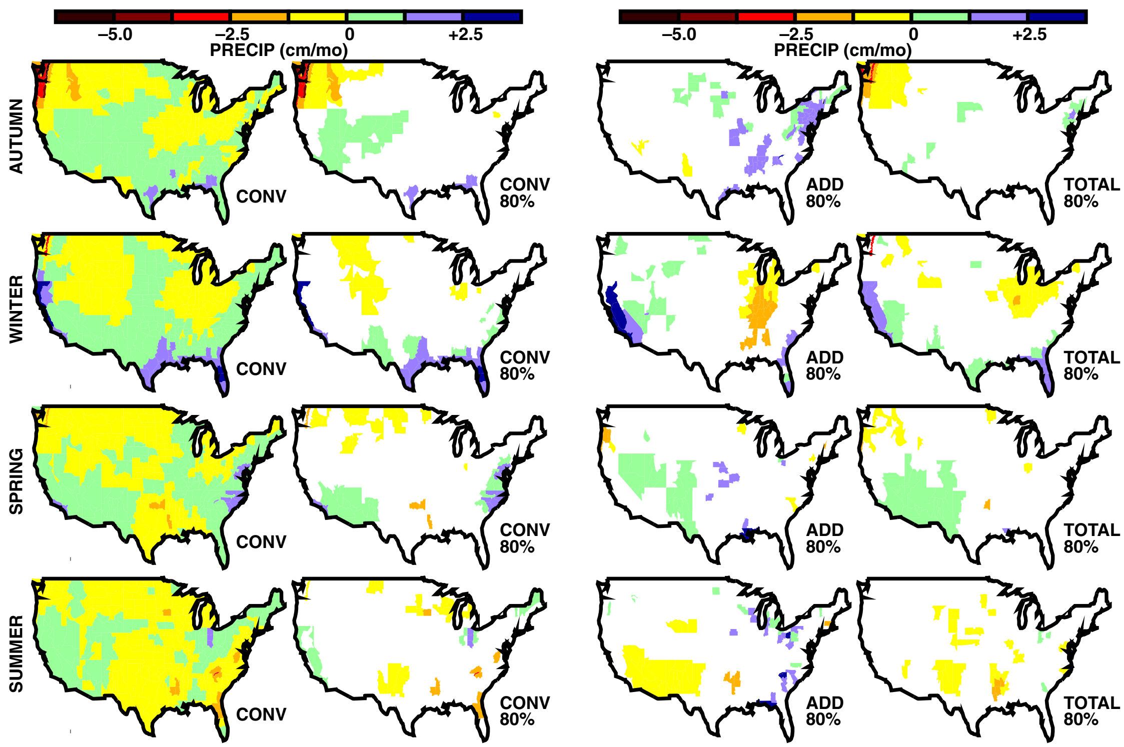

Figure 2: El Niño-Seasonal Average U.S. Precipitation Anomaly Associations. Shown as in Figure 1.

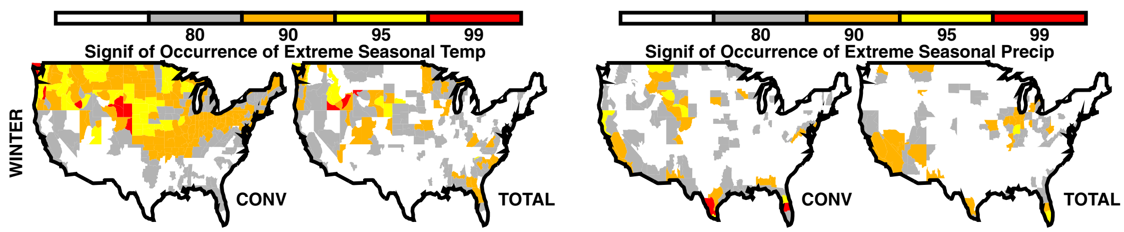

Figure 3: Regions in which the occurrence of upper quintile extreme seasonal anomalies are statistically significant (at 80%, 90%, 95%, 99%). Temperature anomaly results on the left; precipitation on the right. Columns 1 and 3 for conventional years (CONV); columns 2 and 4 for additional years (ADD).